Welcome to

NASA Applied Remote Sensing Training Program (ARSET) Webinar Series

Introduction to Remote Sensing Data for Flood and Drought Monitoring

Course Dates: Every Tuesday, November 6 - December 4, 2012

ARSET

Applied Remote SEnsing Training

A project of NASA Applied Sciences

NASA Earth Science
Applied Sciences Program

Applications to Decision Making: Eight Thematic Areas

Agricultural Efficiency

Air Quality

Climate

Disaster Management

Ecological Forecasting

Public Health

Water Resources

Weather (Aviation)

Applied Remote Sensing Training (ARSET)

Professional courses on remote sensing applications

•31 courses to date

•Water Resources and Disaster Management
http://water.gsfc.nasa.gov

•Air Quality (since 2008)
http://airquality.gsfc.nasa.gov

•Online courses:
- Required for hands-on courses
- For managers and technical staff

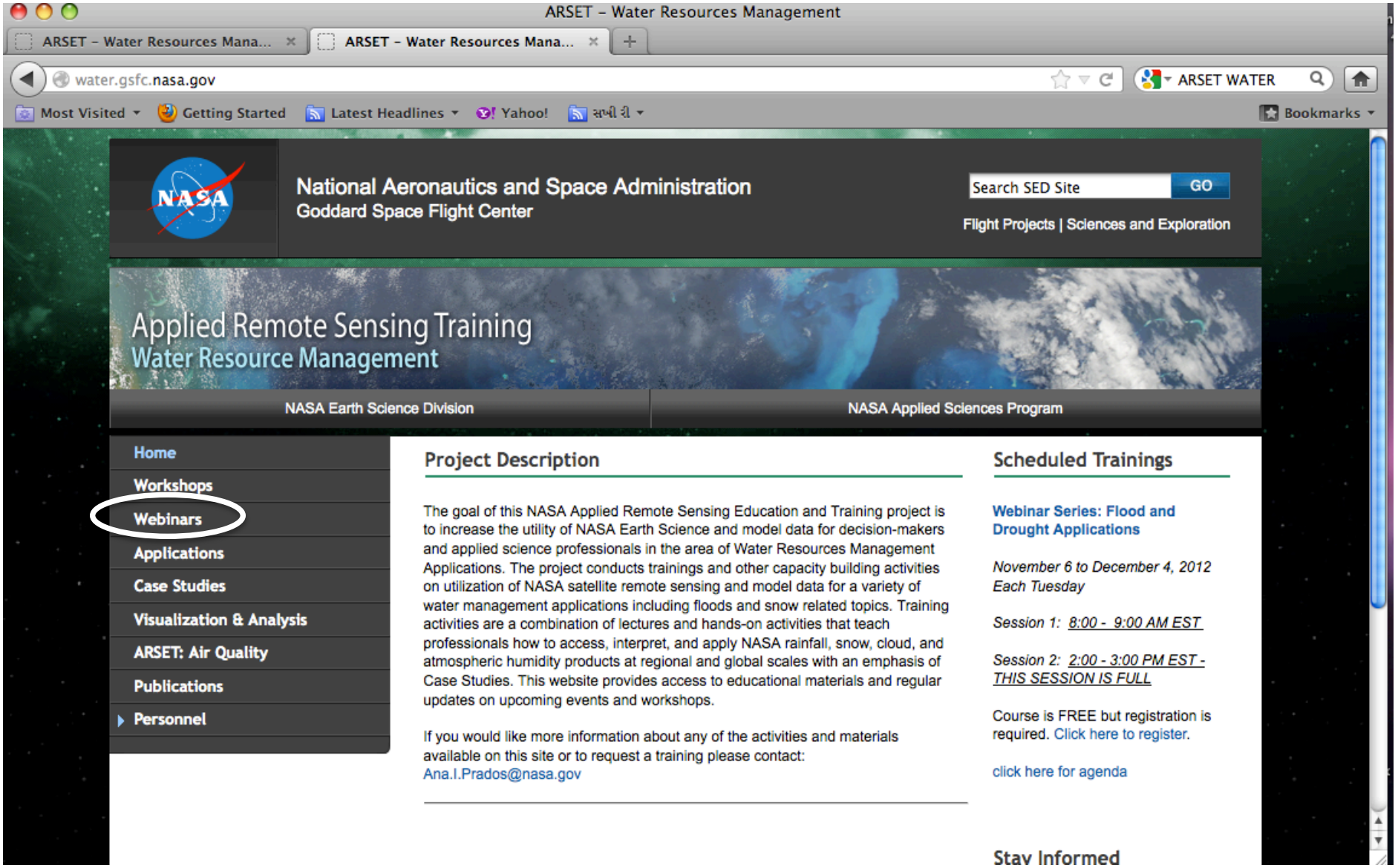
•Hands-on courses:
- More technical
- Basic or advanced

ARSET works directly with agencies in the public and private sectors

Next Water Online Training: Snow Applications:
January 15 – February 5 , 2013

ARSET Water Resource Management

http://water.gsfc.nasa.gov/



Course Structure

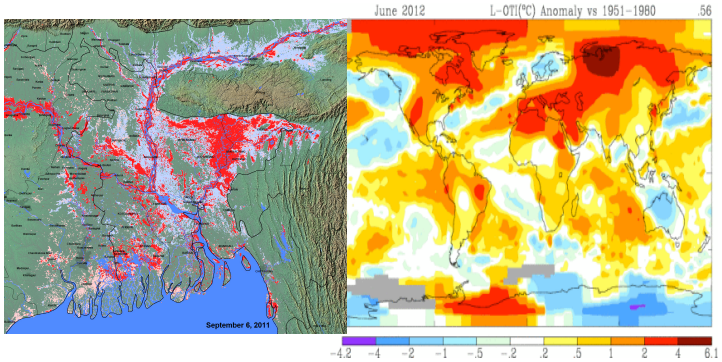
- One lecture per week – every Tuesday between 6 November – 4 December
- Presentations of all webinars can be found on: http://water.gsfc.nasa.gov/webinars/
- Week-4 webinar by Cindy Schmitt from NASA Ames Center
- Two assignments per course (in Week-2 and Week-3)
- Q/A sessions: November 8 (8-9 a.m.)
  15 (2-3 p.m.)
  21 (8-9 a.m.)
  29 (2-3 p.m.)
- 'Chat Window' and call-in number for Q/A during webinars

Course Outline

Week 1

Intro. & Background: Satellite Remote Sensing

Week 2

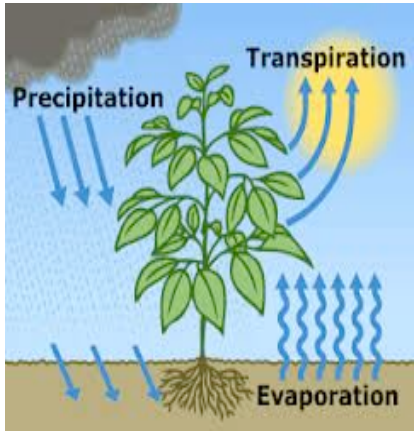


Flood and Drought [Rainfall, Weather and Climate Data]

Week 3

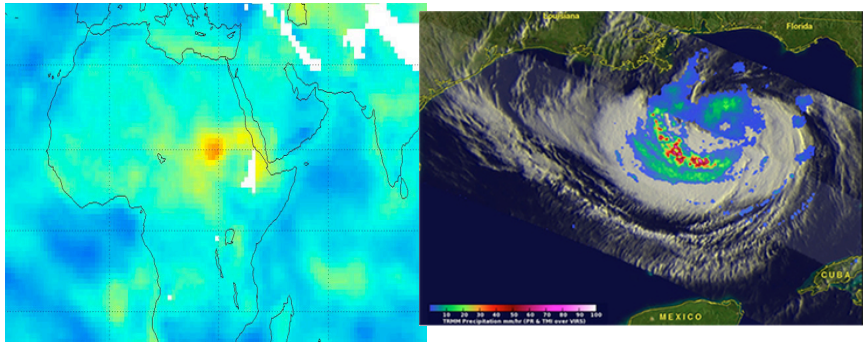
Web-tools

Week 4



Evapotranspiration

Week 5



Data Applications/ Case Studies

Introduction to Remote Sensing Data for Flood and Drought Monitoring

Course Objectives:

- Provide background and introductory information about selected NASA data sets
- Show examples and applications of the data usage for flood and drought monitoring through regional case studies
- Prepare end-users for advanced ‘hands-on’ training for specific applications

Who Can Benefit from ARSET Courses?

- **Public Sector:** Local, state, federal, international regulatory agencies, project managers, health and disaster management agencies, World Bank, United Nations

- **Private Sector:** industry, NGOs, consultants, and other organizations involved in capacity building

- **Scientists/Technical Experts**: Meteorologists, Modelers, Hydrologists, Agriculture, Health and Disaster Researchers

Week 1: Overview of NASA Data from Satellites, Atmosphere and Land Models

- Advantages and limitations of satellite remote sensing observations
- Fundamentals of satellite remote sensing
- Overview of atmosphere and land models

Floods

Flood: An overflow of water onto normally dry land.

It may last for days or weeks.

Flash Flood: A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours.

Can occur within minutes or a few hours of excessive rainfall.

Floods

Meteorology and Hydrological Information Crucial for Flood Monitoring

- Rain Rate and Accumulated Rain Amount
- Snow Melt Rate
- Terrain
- Soil Condition: soil moisture, temperature, and cover
- Reservoir/River Level
- Strom Water Drainage System (urban floods)

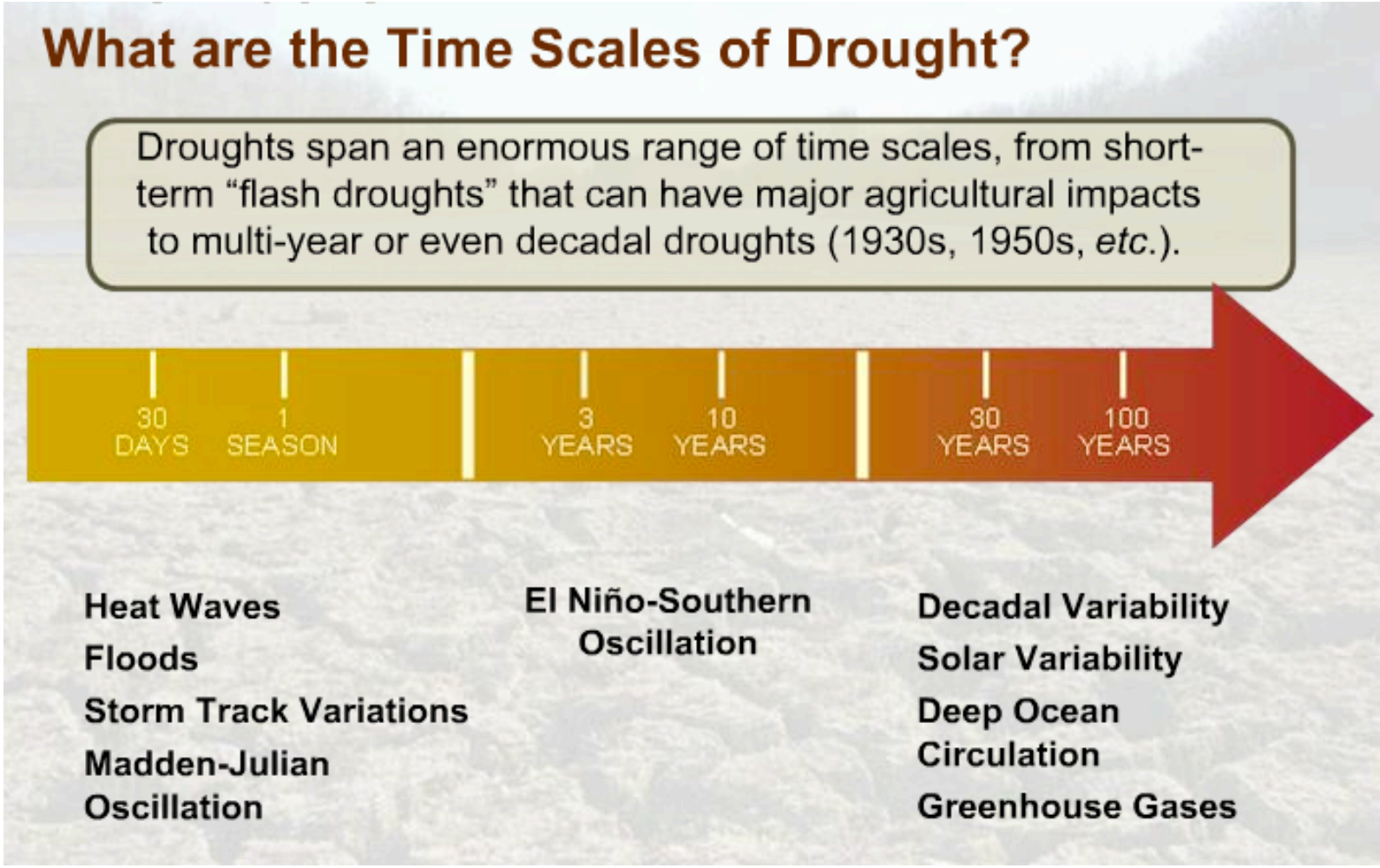
Drought

Meteorological Drought: Deficient rainfall over specific period

Agricultural Drought: precipitation shortages resulting in soil moisture deficits, reduced vegetation/crop.

Hydrological Drought: depletion of surface or subsurface water supply i.e., streamflow, reservoir and lake levels, groundwater.

Drought



From:http://nidis1.ncdc.noaa.gov/
(COMET)

Drought

Meteorology and hydrological information on regional scales and a variety of time scales required for drought monitoring

- Precipitation, Temperature, Humidity, Wind
- Snow cover, Snow Pack
- Streamflow, Surface and Sub-surface Water Levels
- Soil Moisture
- Vegetation, Evapotranspiration

NASA satellites and atmosphere-land models provide global scale geophysical quantities on hourly, daily, seasonal, multi-year time scales useful for flood and drought monitoring

- Rain
- Temperature
- Humidity
- Winds
- Soil Moisture
- Snow/Ice
- Clouds
- Terrain
- Ground Water
- Vegetation Index
- Evapotranspiration
- Run off

For direct applications and for inputs to hydrology and crop models

All other quantities are available from satellite observations as well as from models
Quantities in green are derived from satellite observations
Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

The focus of the present course:

- **Rain**
- **Temperature**
- **Humidity**
- **Winds**
- **Evapotranspiration**

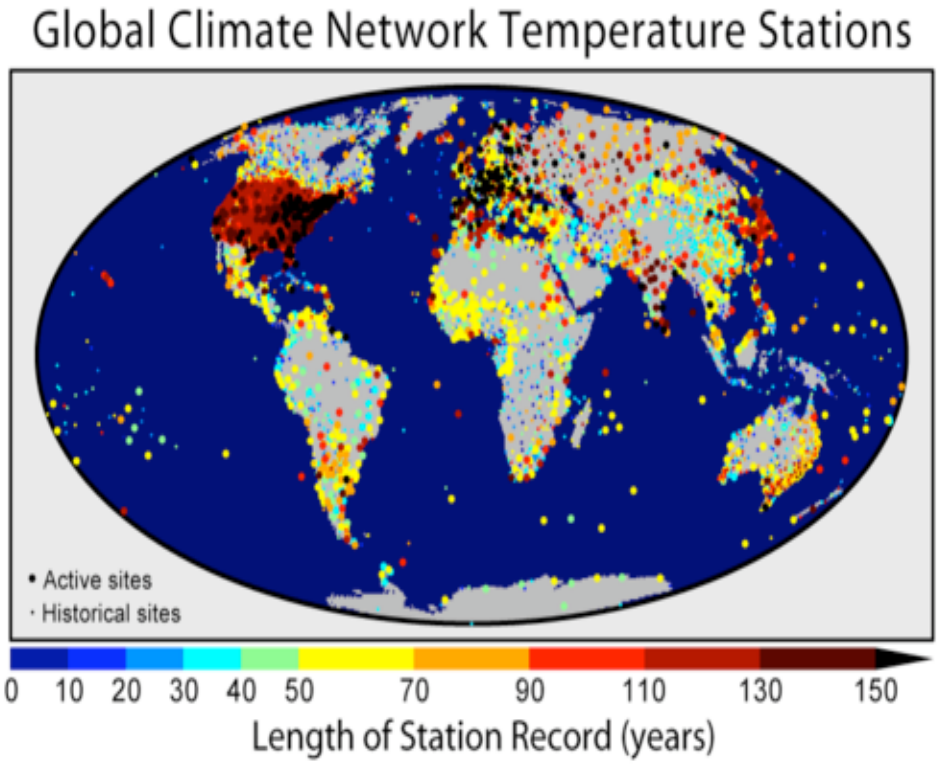
Upcoming courses in 2013-14:

- Snow/Ice
- Evapotranspiration
- Soil Moisture

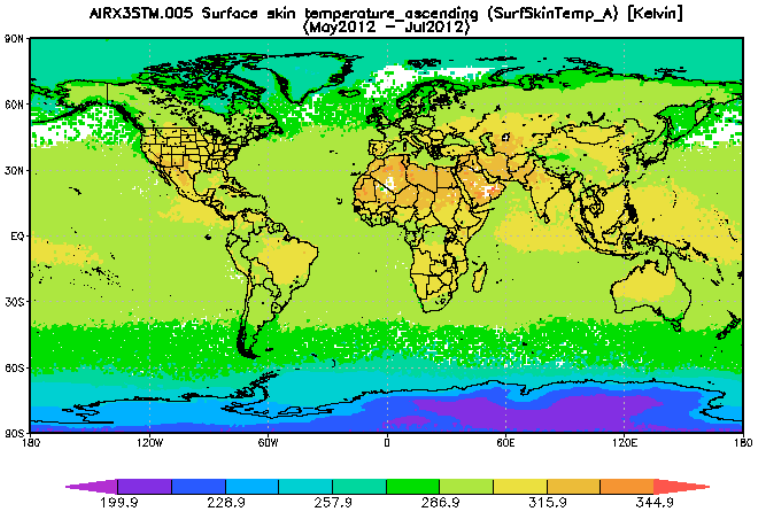
Advantages of Remote Sensing observations

Remote Sensing observations provide information where there are no ground-based measurements

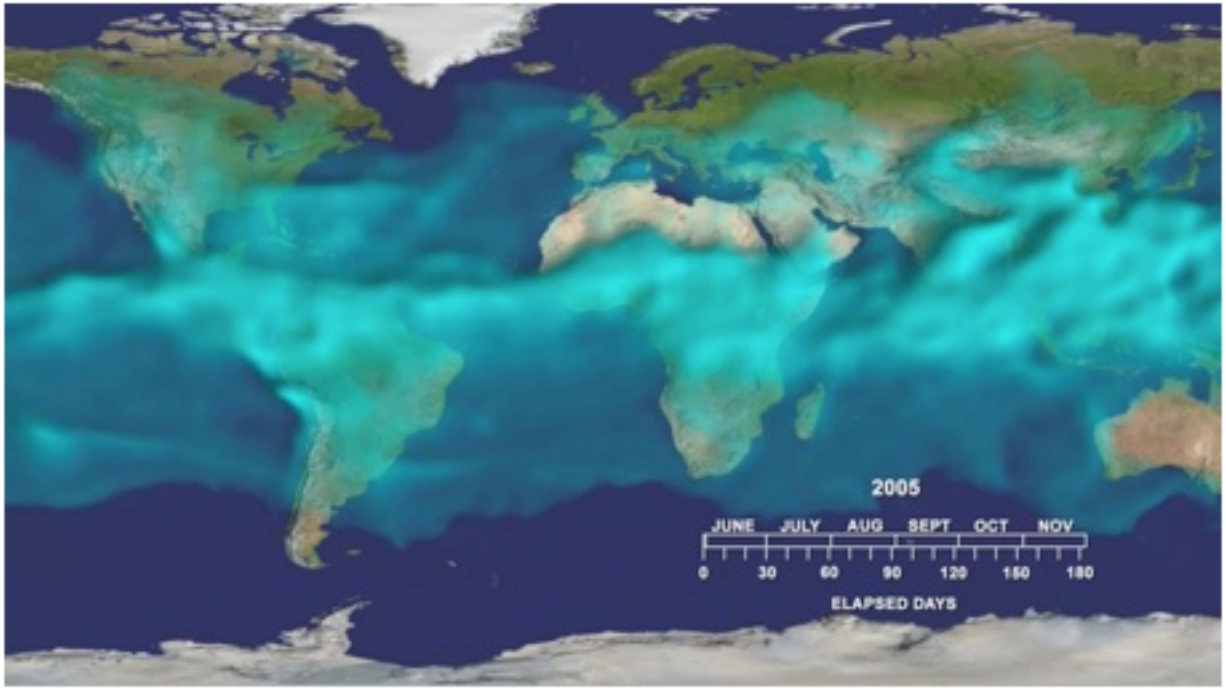
Non-uniform spatial and temporal coverage by surface stations



Summer time surface air temperature derived from measurements taken by Atmospheric Infrared Sounder instrument on-board NASA's Aqua satellite



Remote Sensing observations provide globally consistent measurements



Variations in the three dimensional distribution of atmospheric water vapor, where higher altitudes appear brighter. Made with AIRS data retrieved during summer and fall, 2005.

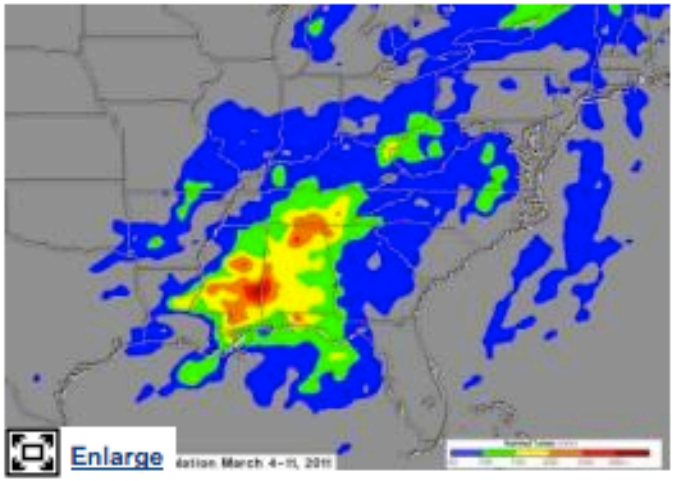
Image credit: Dr. Vincent J. Realmuto, Earth Surface Science Group, JPL

3-dimensional atmospheric moisture field from Atmospheric Infrared Sounder (AIRS)

Remote Sensing observations provide large scale perspective

TRMM maps flooding along US East Coast from massive storm

March 14, 2011



The analysis indicated that the greatest total rainfall for the past week was over 300 mm (~11 inches) and was located over Alabama and Mississippi (in dark red). Some of the extremely heavy rainfall in this area was associated with tornado spawning thunderstorms. Much of the eastern United States was affected by rainfall totals of over 50 mm (~2 inches). Credit: NASA/SSAI, Hal Pierce

The massive rain storm that stretched from New York to Florida last week dropped some record rainfall and NASA's Tropical Rainfall Measuring Mission (TRMM) satellite measured that rainfall from space.

Fundamentals of Satellite Remote Sensing

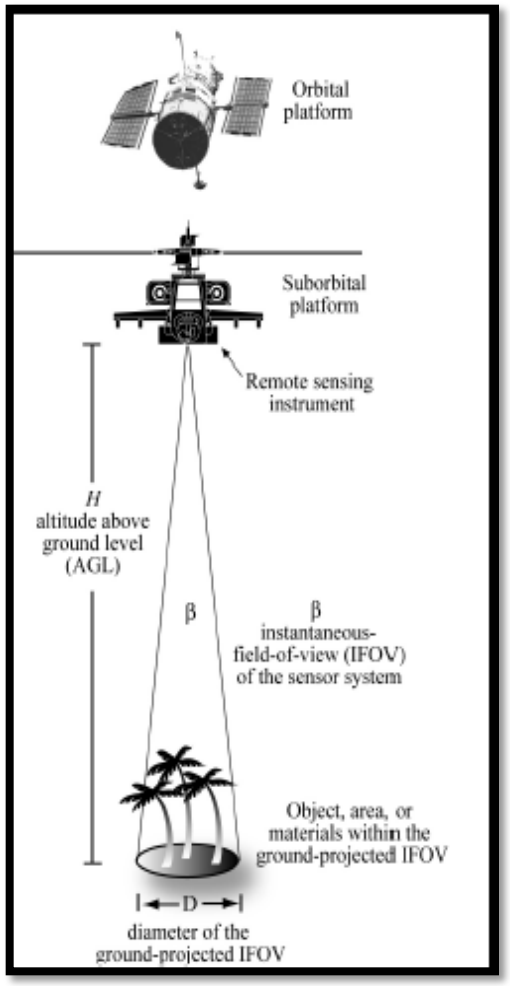
Remote Sensing :

Measurement of a quantity associated with an object by a device not in direct contact with the object

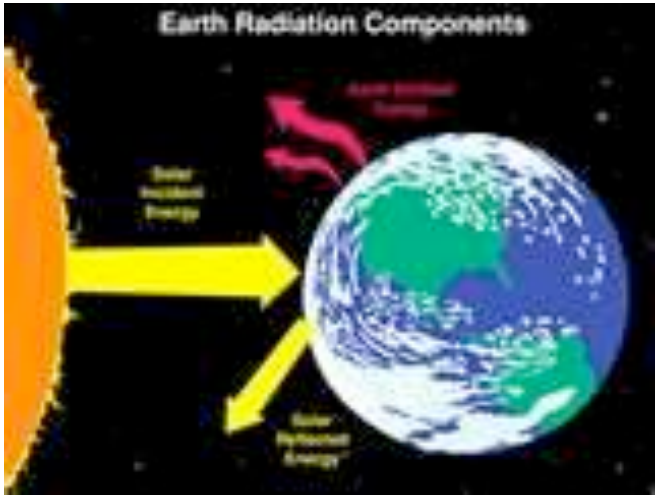
Remote Sensing : Examples

- Platform depends on application
- What information do we want?
- How much detail?
- What type of detail?
- How frequent?

Satellite Remote Sensing: measuring properties of earth-atmosphere system from space



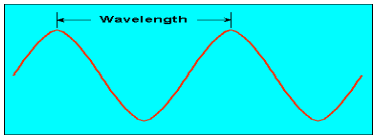
Satellites carry instruments or sensors which **measure electromagnetic radiation** coming from the earth-atmosphere system



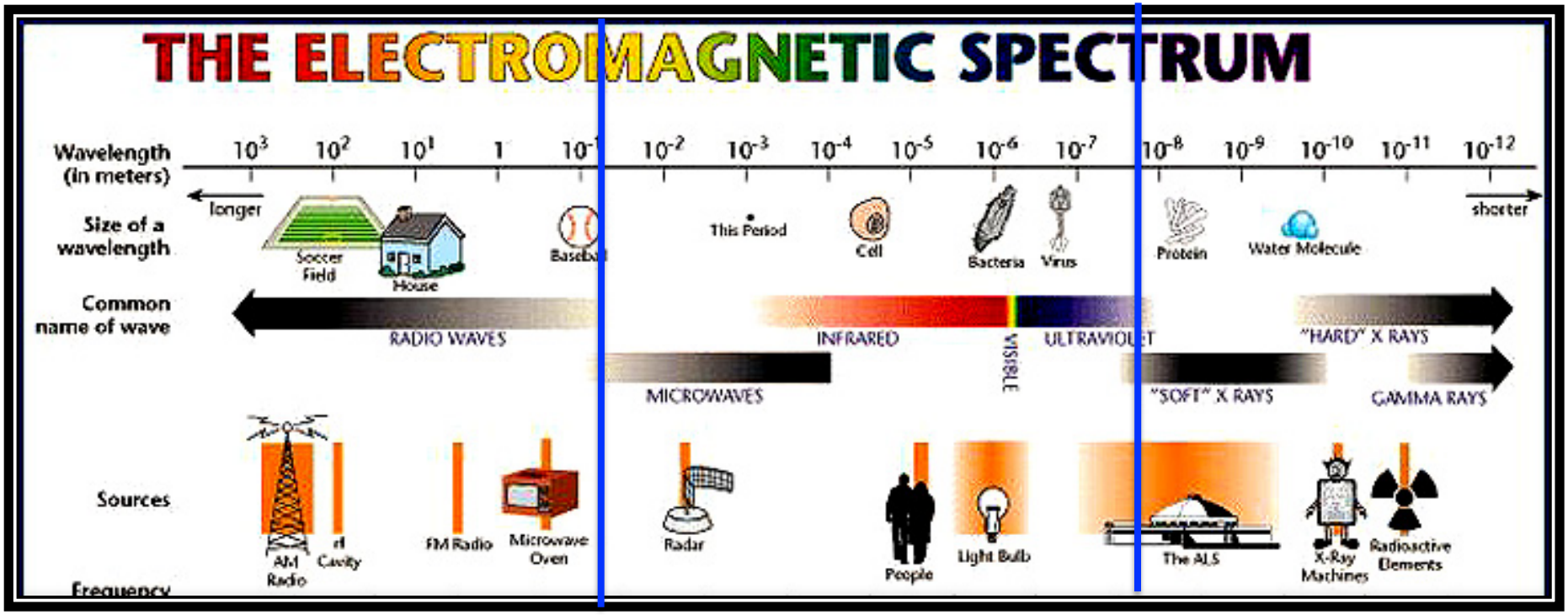
Electromagnetic Radiation

Earth-Ocean-Land-Atmosphere System :

- reflects solar radiation back
- emits Infrared radiation and Microwave radiation



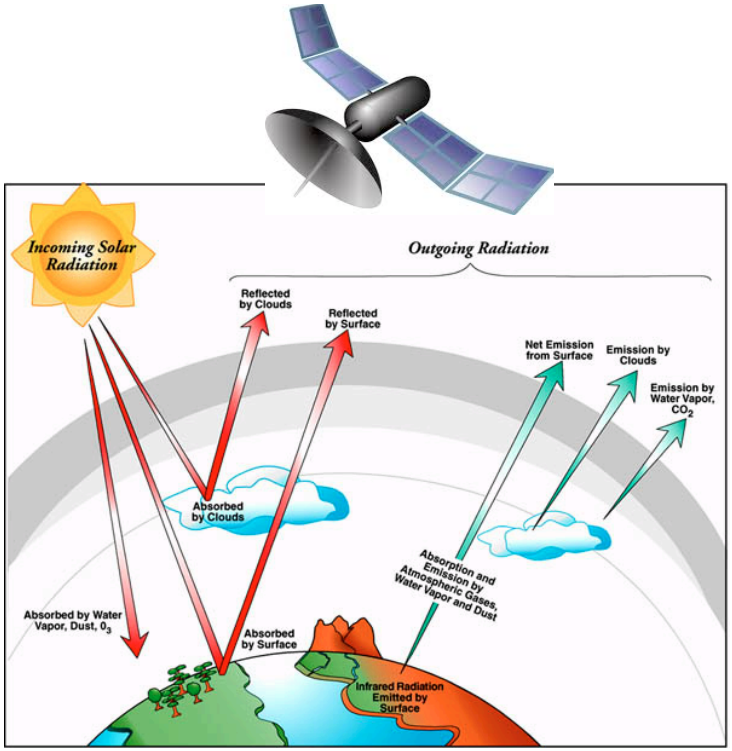
Electromagnetic waves



Satellite Remote Sensing: measuring properties of earth-atmosphere system from space

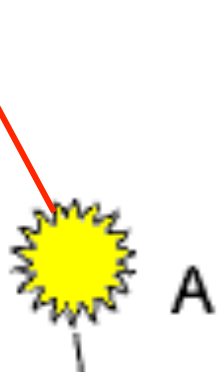
- The intensity of reflected and emitted radiation to space at is influenced by the surface and atmospheric conditions

- Thus, satellite measurements contain information about the surface and atmospheric conditions



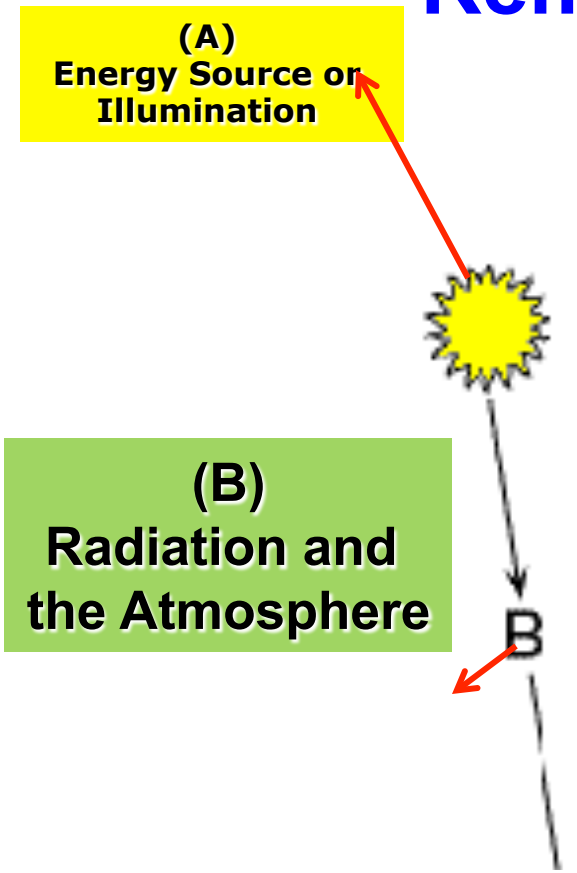
Remote Sensing Process

(A)
Energy Source or Illumination



Reference:
CCRS/CCT

Remote Sensing Process



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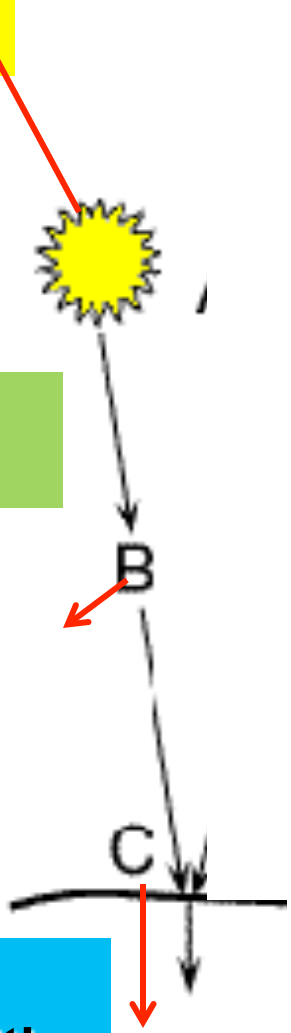
Remote Sensing Process

(A)
Energy Source or Illumination



(B)
Radiation and the Atmosphere

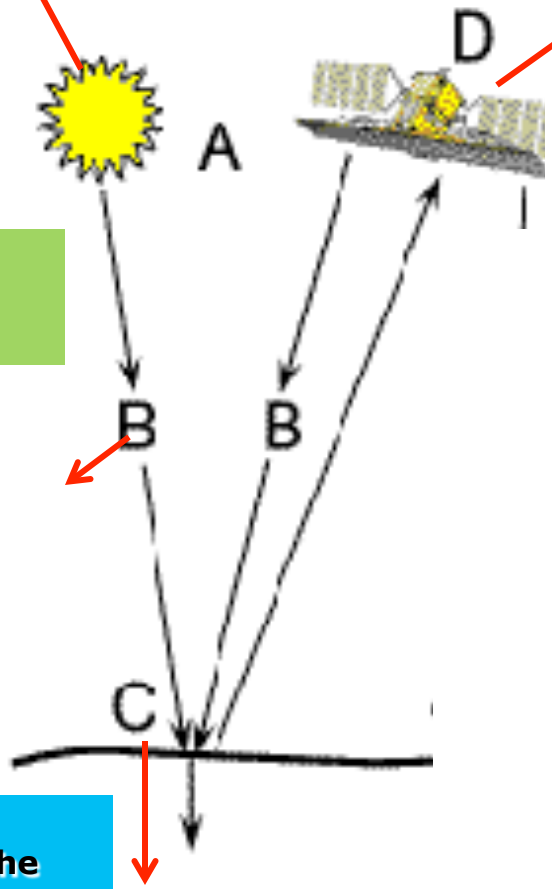
(C)
Interaction with the Target

Reference:
CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor



(B)
Radiation and the Atmosphere

(C)
Interaction with the Target

Reference:
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Remote Sensing Process

(A)
Energy Source or Illumination

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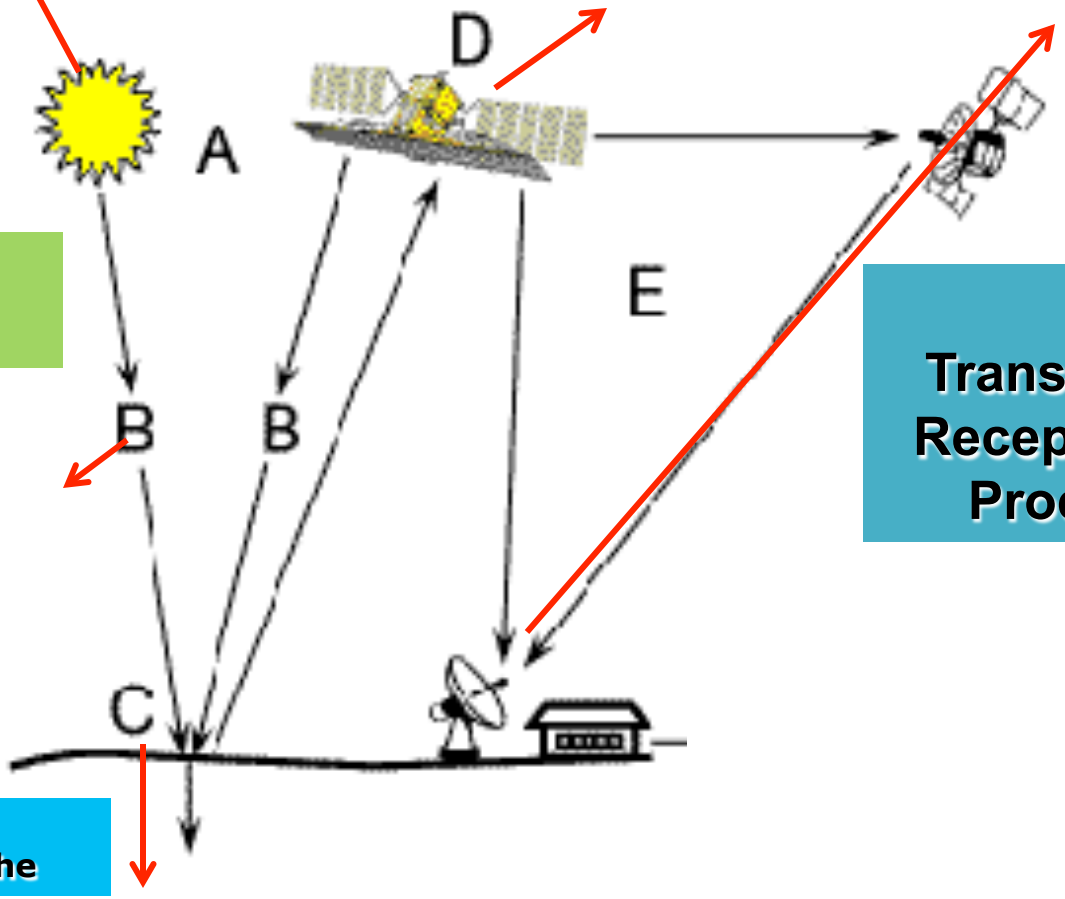
Recording of Energy by the Sensor



(B)
Radiation and the Atmosphere

(E)
Transmission, Reception, and Processing

(C)
Interaction with the Target

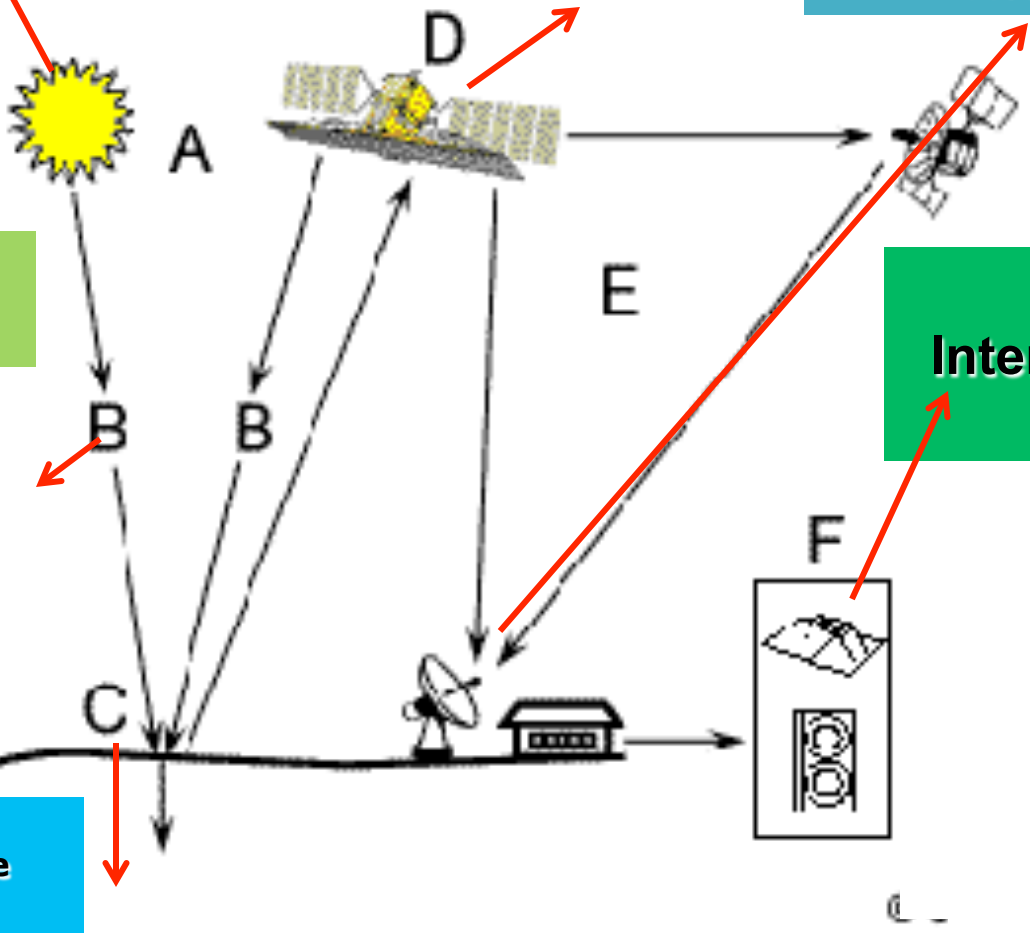
Reference:
CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor

(E)
Transmission, Reception, and Processing



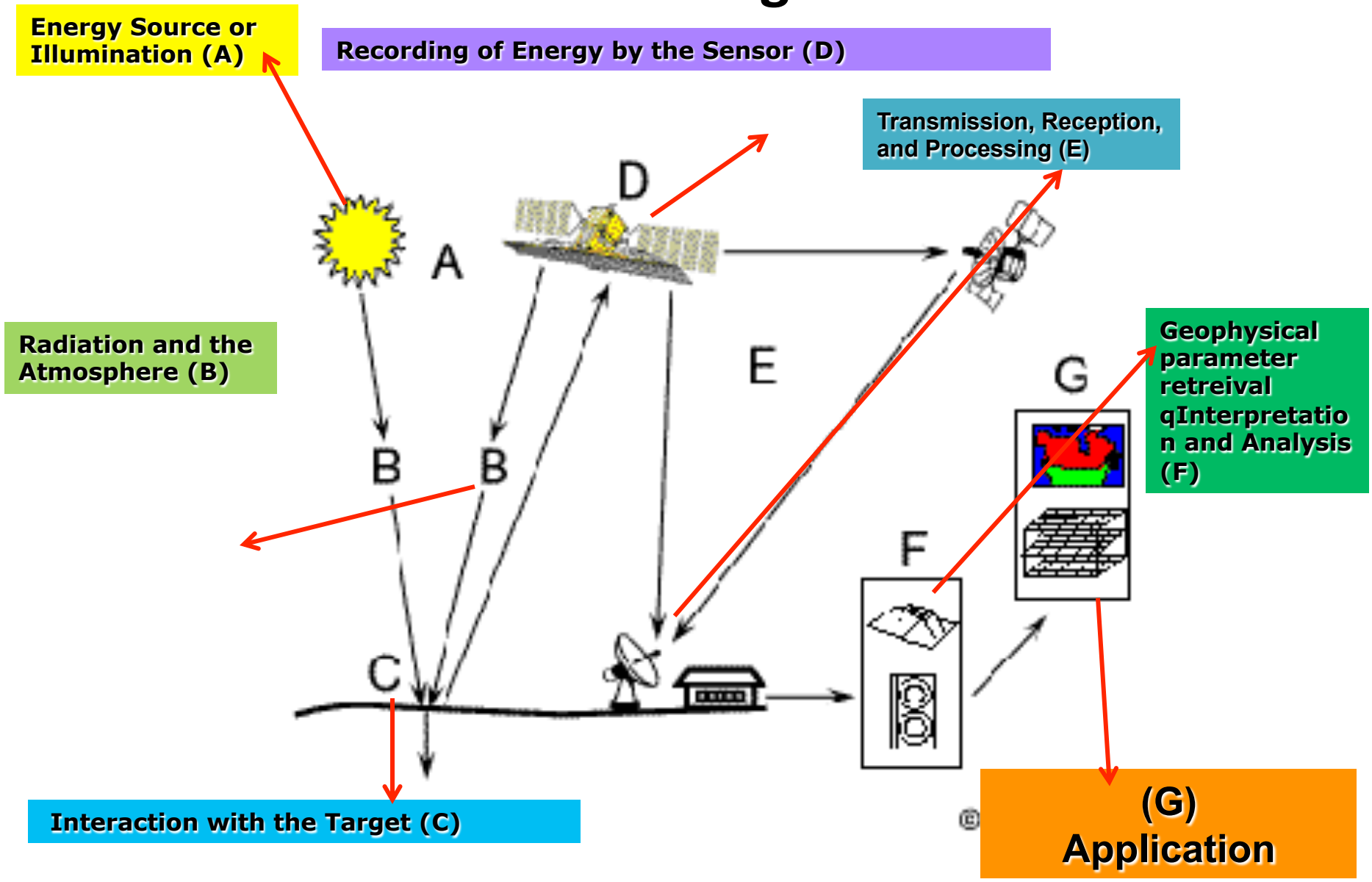
(B)
Radiation and the Atmosphere

(F)
Interpretation and Analysis

(C)
Interaction with the Target

Reference:
CCRS/CCT

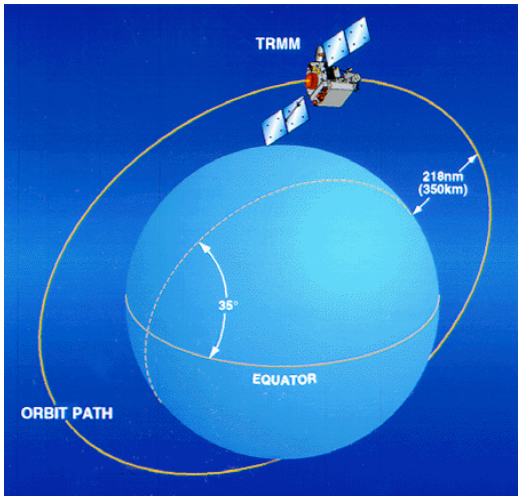
Remote Sensing Process



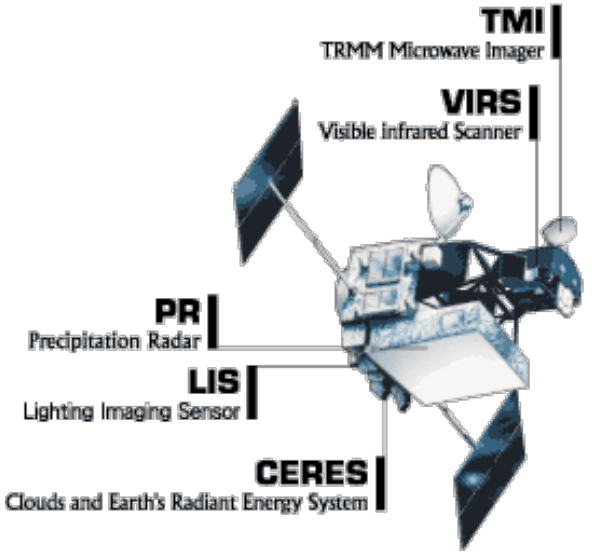
Reference: CCRS/CCT

Satellite Remote Sensing Observations

We need to know:



- Instruments/sensors and types
- Types of satellite orbit around the earth
- Spatial and Temporal Resolution
  Spatial Coverage
- Geophysical quantities derived from the measurements



quality and accuracy of the derived quantities

availability, access, format

applications and usage

Satellite Sensors

Type of Sensors

Spatial Resolution

Temporal Resolution

Spectral Resolution

Radiometric Resolution

Satellite Sensors

Passive remote sensors

Measure radiant energy

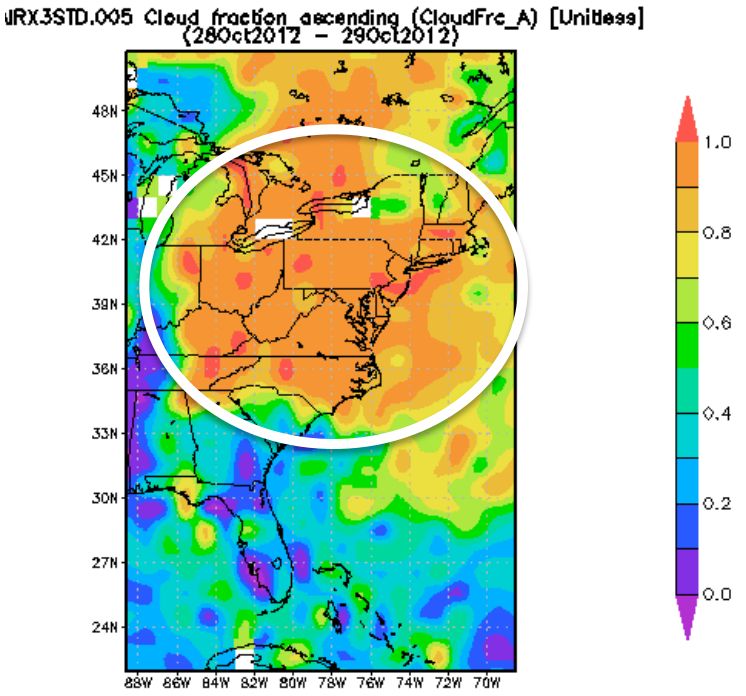
Reflected or emitted by the earth-atmosphere System

Radiant energy is converted to a geophysical quantities

Examples:

MODIS, AIRS, TMI, OMI, CERES

Cloud Fraction
Showing Hurricane Sandy
(28-29 October 2012)



From **Atmospheric Infrared Sounder (AIRS), a passive sensor** on-board Aqua satellite

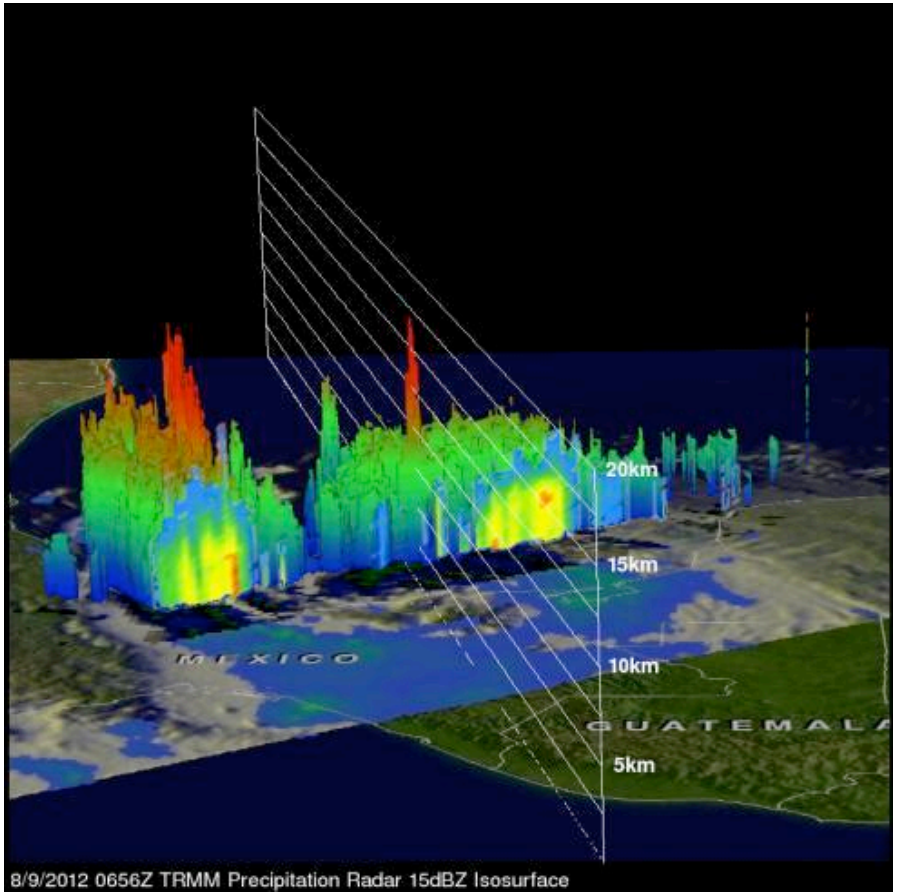
Satellite Sensors

Active remote sensors ‘throw’ beams of radiation on the earth-atmosphere system and measure ‘back-scattered’ radiation

The back-scattered radiation is converted to geophysical parameters

Examples: Precipitation Radar, LIDAR,

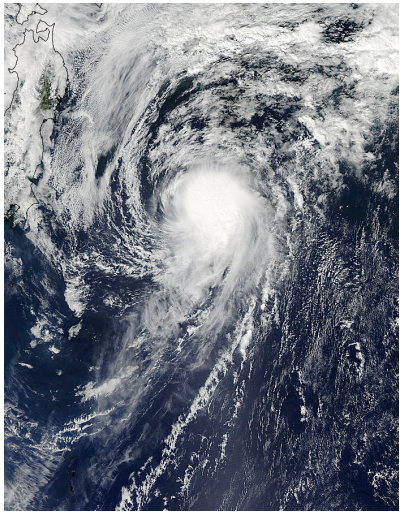
TRMM satellite – **Precipitation Radar, an active sensor,** measuring 3-dimensional reflectivity converted to rain rates for Hurricane Ernesto (August 9, 2012)



Satellite Sensors

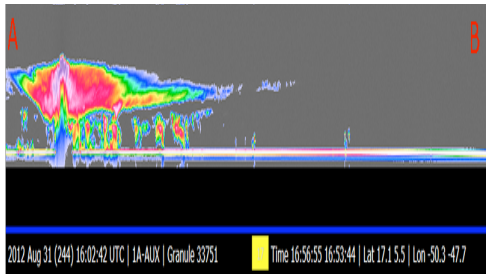
Imagers: Create Images

Examples: MODIS, TMI



Sounders: Provide vertical profiles

Examples: AIRS, Cloud Profiling radar



Spatial and Temporal Resolution of Satellite Measurements

- Depend on satellite orbit configuration and sensor design.

Temporal resolution:

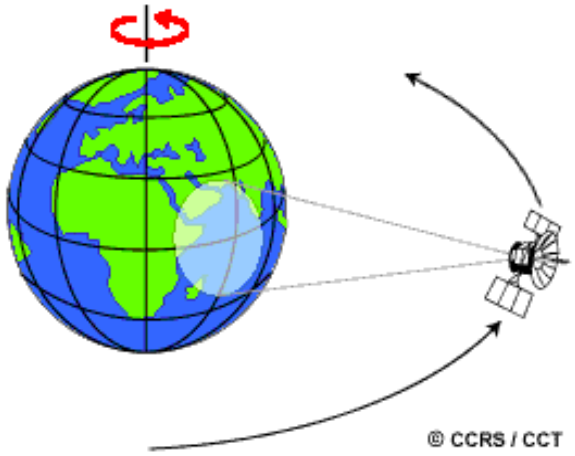
- How frequently a satellite observes same area on earth

Spatial Resolution:

- Decided by its pixel size -- pixel is the smallest unit measured by a sensor

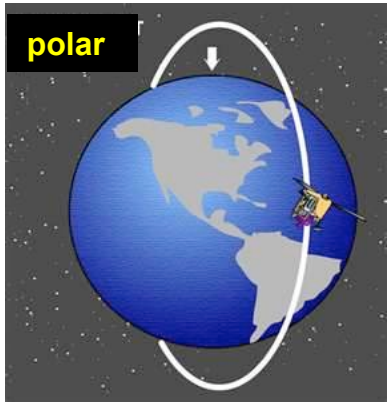
Types of Satellite Orbits

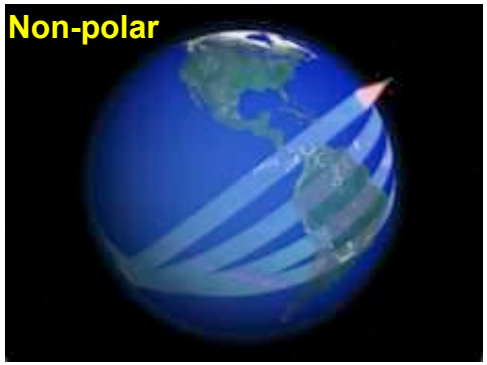
Geostationary orbit



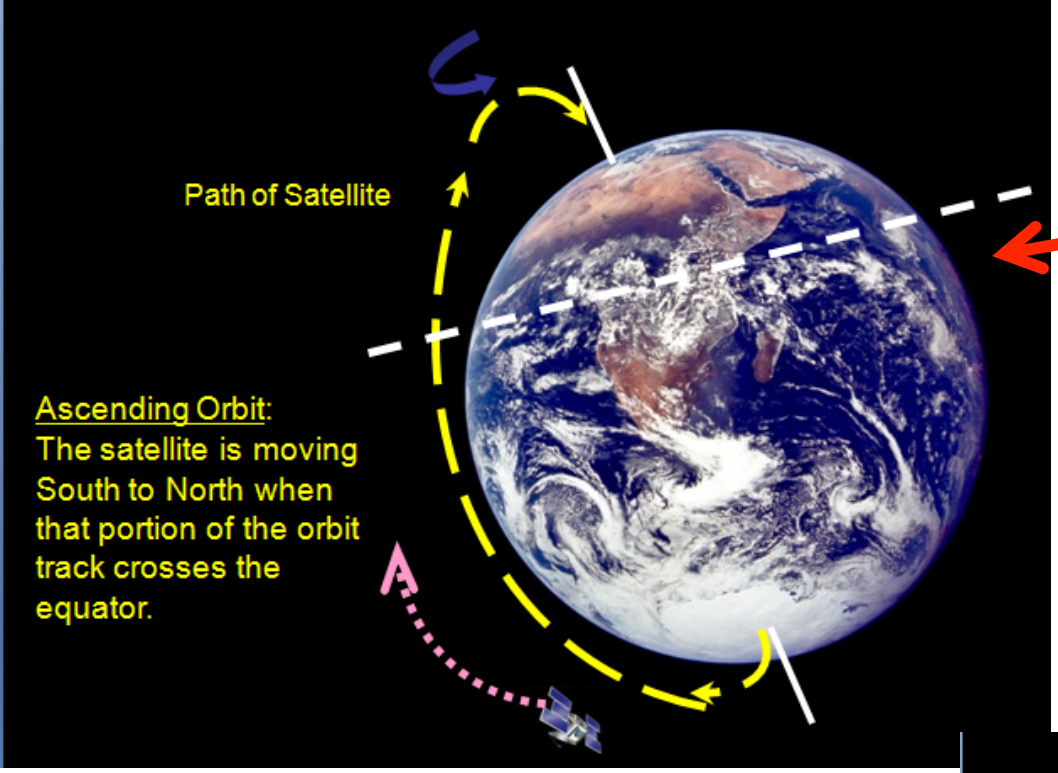
Satellite is at ~36,000 km above earth at equator. Same rotation period as earth's. Appears 'fixed' in space.

Low Earth Orbit (LEO)



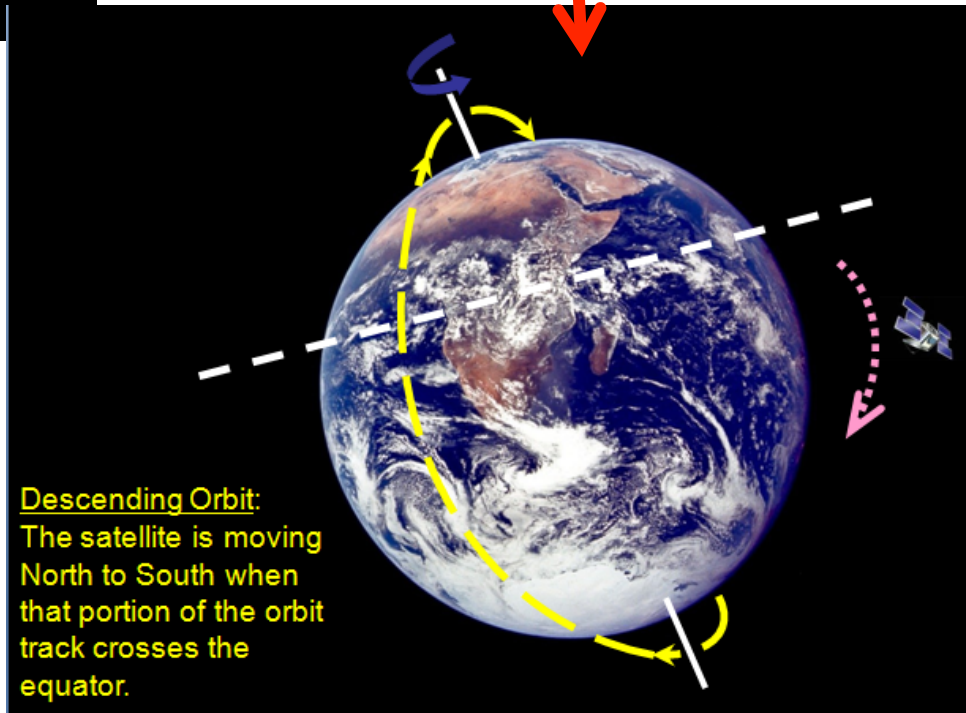


Circular orbit constantly moving relative to the Earth at 160-2000 km. Can be in Polar or non-polar orbit



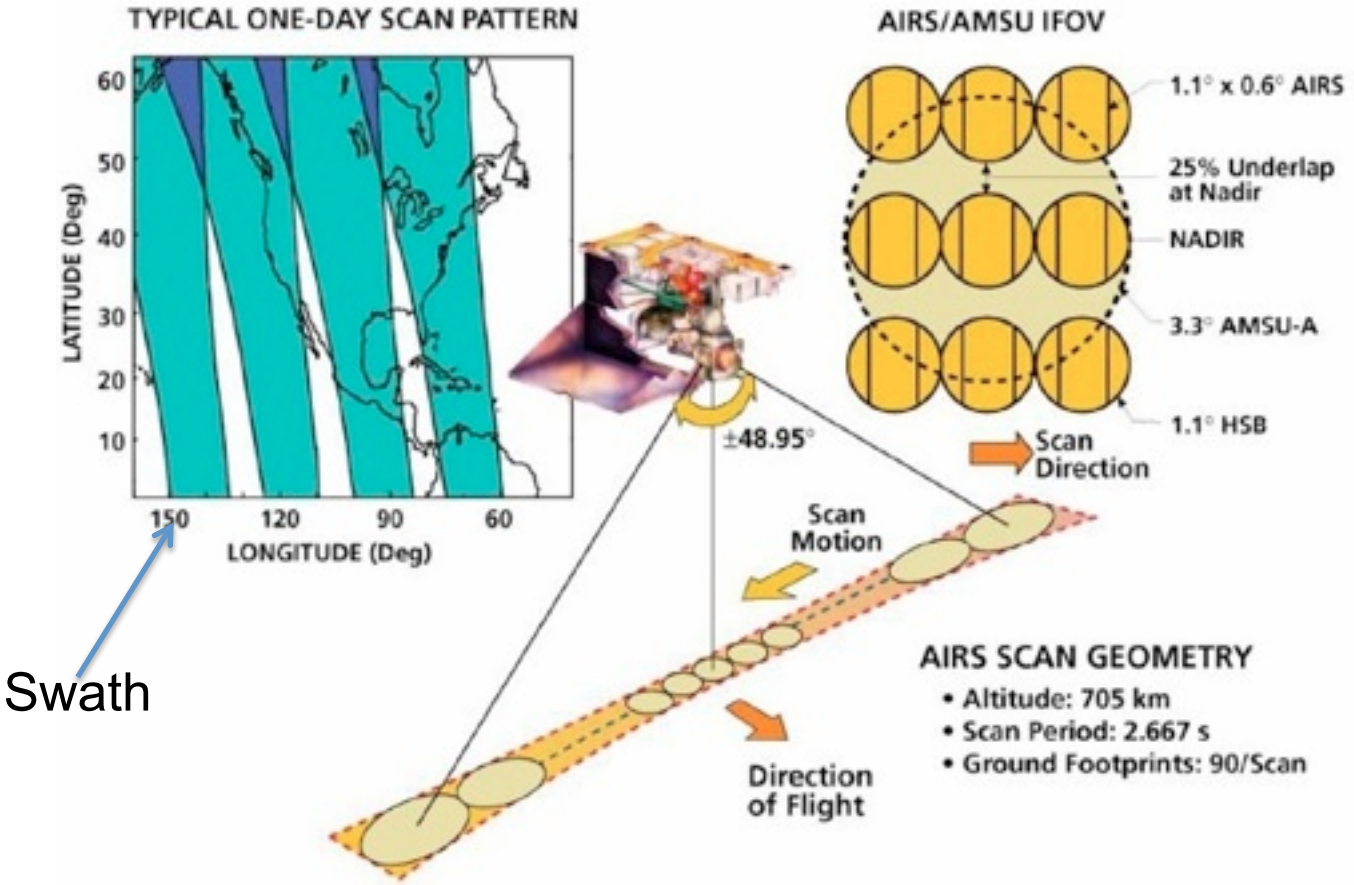
Ascending vs Descending

Polar Orbits



Spatial Resolution

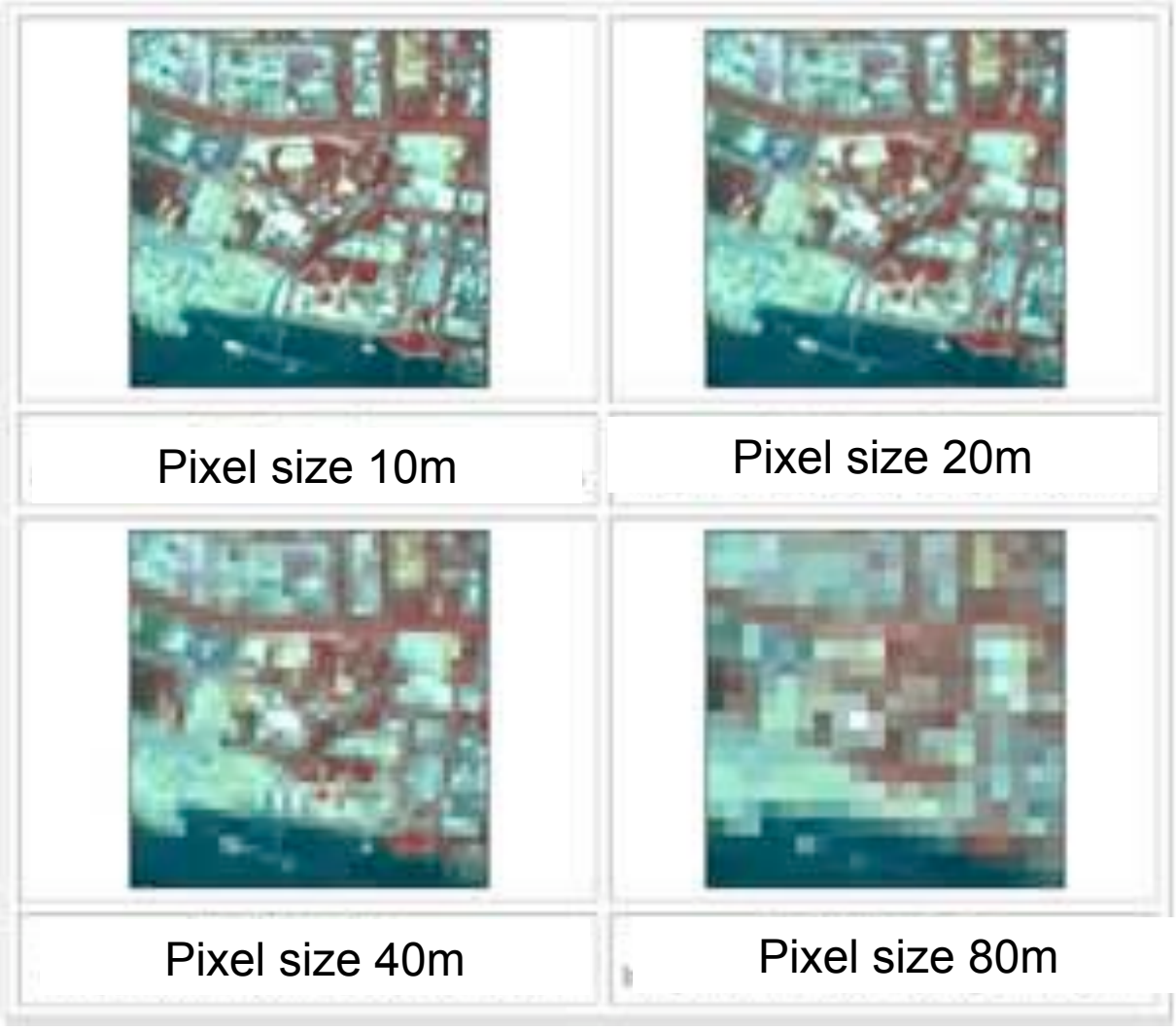
Example (Atmospheric Infrared Sounder)



AIRS is flying on-board NASA's Aqua satellite

Spatial Resolution

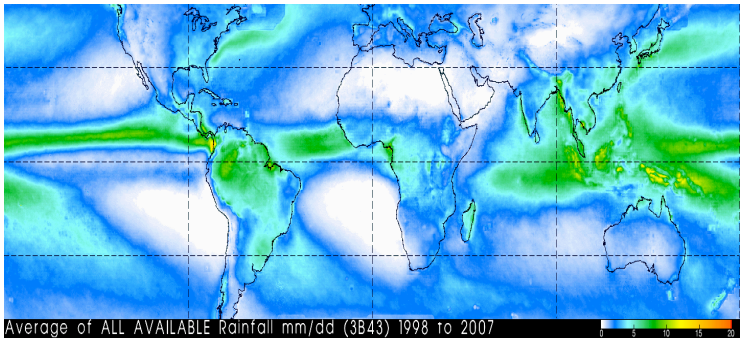
Important for information retrieval



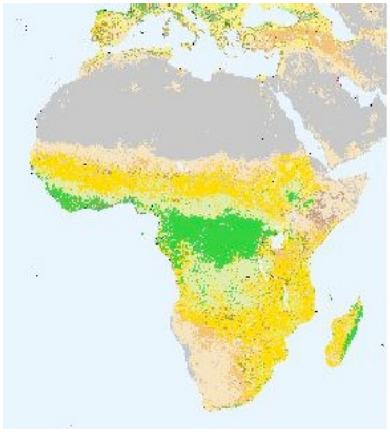
NASA Satellites Measurements with Different Spatial Resolution

Landsat Image of Philadelphia
Spatial resolution: 30 m

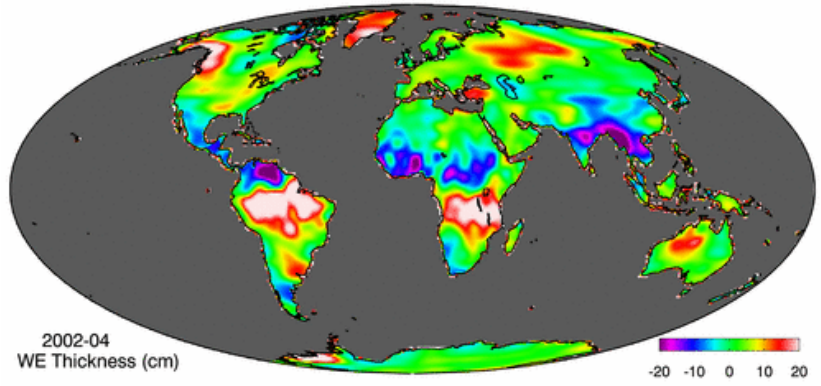
Rain Rate from TRMM
Spatial resolution: 25 km²



Land Cover from Terra/MODIS:
Spatial resolution: 1 km²
(From: http://gislab.jhsph.edu/)



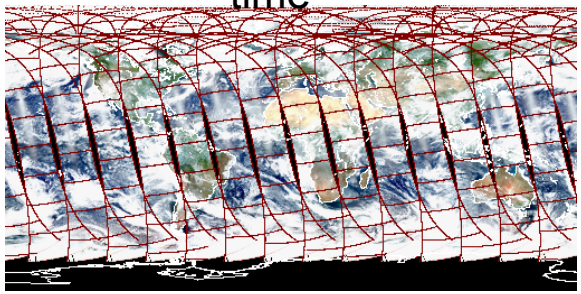
Terrestrial Water Storage Variations from GRACE: Spatial resolution: 150,000 km² or coarser (Courtesy: Matt Rodell, NASA-GSFC)



Spatial Coverage and Temporal Resolution

Polar orbiting satellites: global coverage - but one to two or less measurements per day per sensor. Orbital gaps present. Larger Swath size, higher the temporal resolution.

Aqua ("ascending" orbit) day time



Non-Polar orbiting satellites: Less than one per day. Non-global coverage. Orbital gaps present. Larger Swath size, higher the temporal resolution.

TRMM Image

Geostationary satellites: multiple observations per day, but limited spatial coverage, more than one satellite needed for global coverage.

GOES Image

Spectral Resolution: The number and width of spectral channels. More and finer spectral channels provide remote sensing of different parts of the atmosphere

Radiometric Resolution: Remote sensing measurements represented as a series of digital numbers – larger this number, higher the radiometric resolution, sharper the imagery.

Remote Sensing Observations
Trade Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolutions at the same time
- Several sensors can obtain global coverage every one – two days because of their wide swath width
- Higher resolution polar/non-polar orbiting satellites may take 8 – 16 days for global coverage.
- Geostationary satellites obtain much more frequent observations but at lower resolution due to the much greater orbital distance.

NASA Satellites, Sensors, and Quantities for Flood/Drought Monitoring

NASA Satellites for Flood/Drought Related Quantities

Landsat (07/1972-present)

TRMM (11/1997-present)

Terra (12/1999-present)

Aqua (5/2002-present)

GRACE (3/2002-present)

TRMM: Tropical Rainfall Measuring Mission
GRACE: Gravity Recovery and Climate Experiment

NASA Remote Sensing Quantities for Flood/Drought Monitoring

Satellite	Sensors	Quantities
TRMM	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible Infrared Scanner (VIRS)	Rain Rate, Vertical Rain Rate Profile, Accumulated Rain
Terra and Aqua	MODerate Resolution Imaging Spectroradiometer (MODIS)	Snow Cover, Vegetation Index, Leaf Area Index, Land Cover
Aqua	Atmospheric Infrared Sounder (AIRS) Advanced Microwave Scanning Radiometer for EOS (AMSR-E)	3-dimensional Atmospheric Temperature and Humidity Snow Water Equivalent, Sea Ice, Soil Moisture, Rain Rate
Landsat	(Enhanced) Thematic Mapper (ETM)	Vegetation Index, Leaf Area Index, Land Cover
Grace	K-Band Ranging Assembly	Terrestrial Water

Satellite Products
Limitations

- There are multiple sources of the same products, with varying spatial/temporal resolutions and accuracies

- There are many assumptions and approximations in going from raw data to specific quantity such as rain amount or

- Data quality can range from excellent to poor depending on:
  - Instrument capabilities
  - Instrument calibration and performance
  - The algorithms used to interpret the data

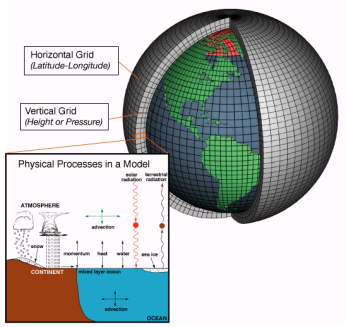
NASA Model-derived Quantities for Flood/Drought Monitoring

Value-added Information

Remote Sensing + Surface Observations + Numerical Models

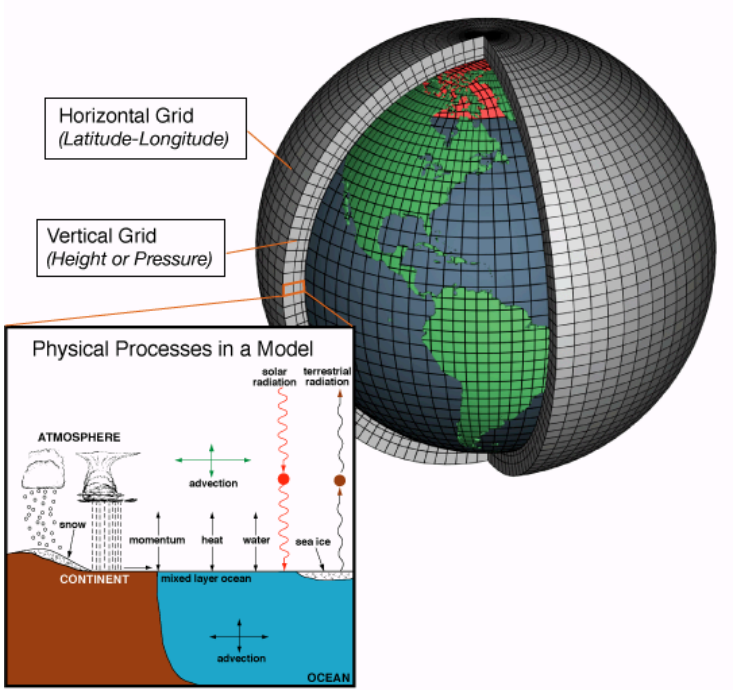
Satellite Data

surface Measurements and In-Situ Data



Numerical Models

Modeling of the atmosphere-Land-Ocean Systems



- Laws of physics in terms of mathematical equations to represent atmosphere, ocean, land systems
- Applied horizontal and vertical grids by using numerical methods
- **Use observations to represent the atmosphere-ocean-land system** at a given time to deduce how the system will evolve over space/time
- Models use physical/statistical/empirical techniques to represent environmental processes

NASA Models for Weather, Climate, and Hydrological Quantities

(Atmosphere-Ocean-Land Models)

- GEOS-5 : The Goddard Earth Observing System Version 5
- MERRA: Modern Era Retrospective-analysis for Research and Application
- GLDAS : Global Land Data Assimilation System
- NLDAS : North American Land Data Assimilation System

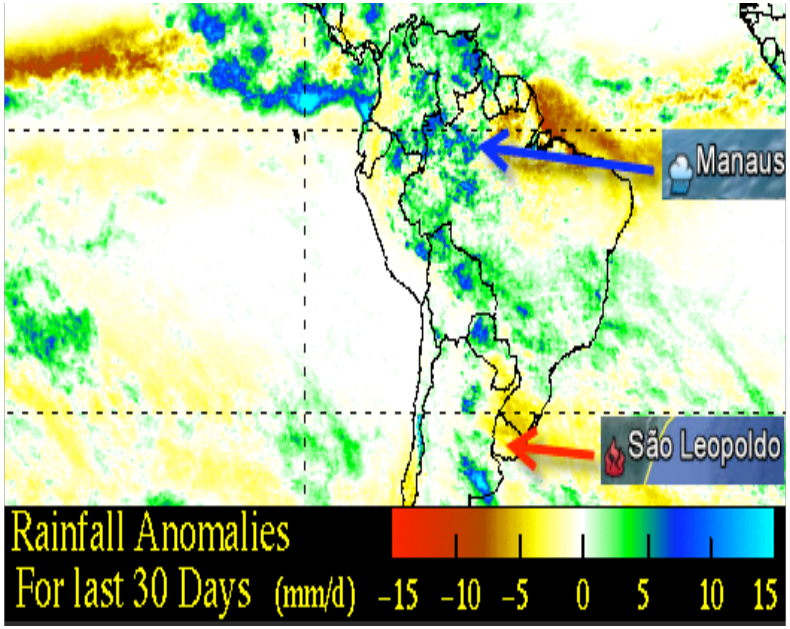
NASA Models and Flood/Drought Related Quantities

Models	Quantities
MERRA	3-dimensional Winds, Temperature, Humidity, Clouds, Rain Rate ,Snow Mass, Snow Cover, Snow Depth, Surface Snowfall Rate, Evapotranspiration
GLDAS/NLDAS	Evapotraspiration, Multi-layer Soil Moisture, Snowfall Rate, Snow Melt, Snow-Water Equivalent, Surface and Sub-surface Runoff

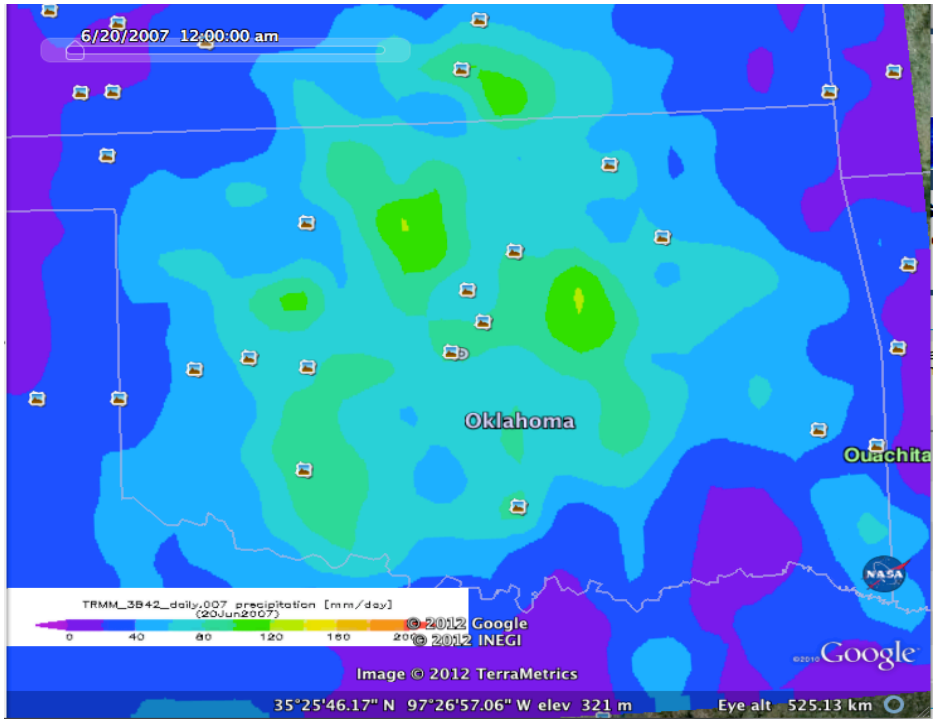
Model-derived Quantities
Trade-offs

- Help blend remote sensing and in situ observations – provide geophysical variables on uniform spatial latitude-longitude grids, and at regular intervals.
- Provide variables which are not directly observable, for example, 3-D humidity movement in the atmosphere
- Help understand processes water cycling in the climate system and provide prediction capability
- Use many approximations and assumptions in representing physical processes – as good as our understanding
- There are multiple models, with varying spatial/temporal resolutions and accuracies.

Examples: Flood and Drought Monitoring

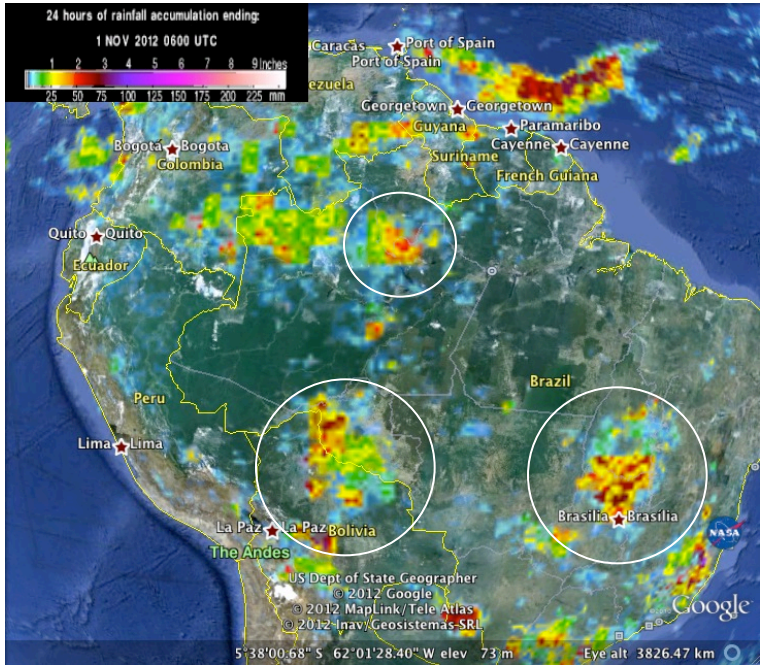


Rainfall deviation observed from TRMM show flood and drought conditions over Brazil (5/25/2012)

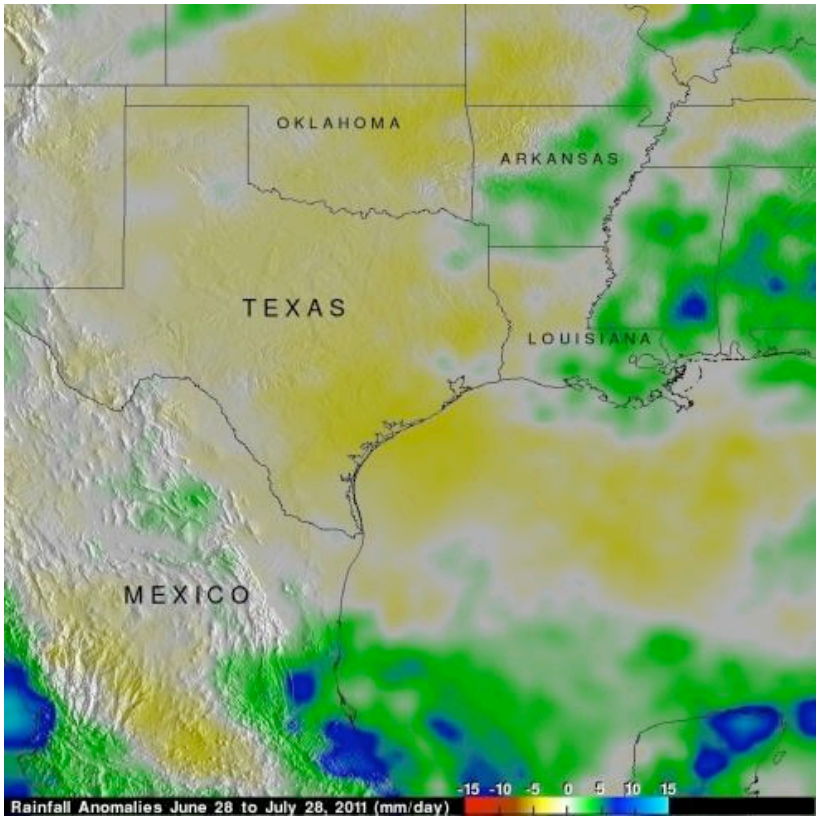


Heavy rains and flooding over Oklahoma as observed from TRMM (6/20/2007)

Examples: Flood and Drought Monitoring



Flood Potential from TRMM on November 1, 2012.



Texas has been suffering from extreme drought for more than a year -- Rainfall deficit over Texas observed from TRMM [June-July 2011]

NASA Remote Sensing and Model-derived Water Resource Quantities

- NASA remote sensing and model-based data are FREE
- Web-based tools available for data access, and analysis, and downloading
- Choices of quantities from various sources according to applications and end-user needs
- ARSET Team directly works with end-users through ‘hands-on’ trainings to facilitate applications and decision support activities with NASA data.

Thank You!